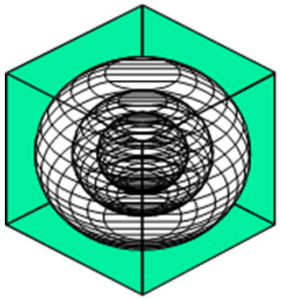
COST-EFFECTIVE ENERGY EFFICIENCY MEASURES FOR ABOVE CODE (2003 AND 2009 IECC) RESIDENTIAL BUILDINGS IN THE CITY OF ARLINGTON

A Research Project for the City of Arlington

August 4, 2011



ENERGY SYSTEMS LABORATORY

Texas Engineering Experiment Station
Texas A&M University System

Background

- Reviewed two years of building energy compliance reports from 2008 to 2010 for 21 residential projects in the CoA.
  - Results of the review: Summary of above-code approaches that have been made in the CoA during the 2008-2010.
- Results of the current project: Recommendations of 17 energy efficiency measures (EEMs) to maximize energy savings for residential buildings in the CoA with
  - estimated cost of the improvement,
  - simple payback calculations, and
  - emissions savings.

Methodology

- ESL simulation model based on the DOE-2.1e of 2003 and 2009 IECC code-compliant, single family residence for Tarrant County
- Two options based on the choice of heating fuel type:
  - (a) Electric/gas house: gas-fired furnace for space heating, and gas water heater for domestic water heating
  - (b) All-electric house: heat pump for space heating, and electric water heater for domestic water heating
- A total of 17 energy efficiency measures (EEMs)
- Solar measures using PV-F Chart and F-Chart programs
- Implementation costs of each measure with simple payback

Methodology

- 2,325 ft^2, square-shape, one-story, single-family detached house
- 50% Energy Star permanent CFL or fluorescent lamps
- HVAC and duct systems in unconditioned attic

Characteristics	Assumptions		Comments
	2003 IECC for CoA	2009 IECC for CoA	
Building			
Building Type	Single family, detached house		
Gross Area	2,325 sq. ft. (48.21 ft. x 48.21 ft.)		
Number of Floors	1		
Floor to Floor Height (ft.)	8		
Orientation	South facing		
Construction			
Construction	Light-weight wood frame with 2x4 studs spaced at 16" on center		
Floor	Slab-on-grade floor		
Roof Configuration	Unconditioned, vented attic		
Roof Absorptance	0.75		Solar reflectance SR= 0.25
Ceiling Insulation (hr-sq.ft.-°F/Btu)	R-38	R-30	
Wall Absorptance	0.75		Assuming brick facia exterior
Wall Insulation (hr-sq.ft.-°F/Btu)	R-11	R-13	
Slab Perimeter Insulation	None		
Ground Reflectance	0.24		Assuming grass
U-Factor of Glazing (Btu/hr-sq.ft.-°F)	0.47	0.5	
Solar Heat Gain Coefficient (SHGC)	0.4	0.3	
Window Area	18% of conditioned floor area	15% of conditioned floor area	This corresponds to 27.13% and 22.61% window-to-wall area ratio for the assumed 2003 and 2009 base case building configuration, respectively.
Exterior Shading	None		
Roof Radiant Barrier	No		Roof radiant barrier emissivity=0.05
Slope of Roof	5:12		Steep slope (5:12 Slope of roof =23 degrees)
Space Conditions			
Space Temperature Set point	68°F Heating, 78°F Cooling, 5°F setback/setup	72°F Heating, 75°F Cooling, no set-back/setup	
Internal Heat Gains	1.095 kW (modeled as 0.547 kW for lighting and 0.547 kW for equipment)		This assumes heat gains from lighting, equipment and occupants.
Number of Occupants	None		Assuming internal gains include heat gain from occupants
Mechanical Systems			
HVAC System Type	Gas & Electric Type: Electric cooling (air conditioner) and natural gas heating (gas fired furnace)		
	All Electric Type: Electric cooling and heating (air conditioner with heat pump)		
HVAC System Efficiency	Gas & Electric Type: SEER 13 AC, 0.78 AFUE furnace		
	All Electric Type: SEER 13 AC, 7.7 HSPF heat pump		
Cooling Capacity (Btu/hr)	55,800		500 sq. ft./ton
Heating Capacity (Btu/hr)	55,800		1.0 x cooling capacity
DHW System Type	Gas & Electric Type: 40-gallon tank type gas water heater with a standing pilot light		
	All Electric Type: 50-gallon tank type electric water heater (without a pilot light)		
DHW Heater Energy Factor	Gas & Electric Type: 0.594		Gas: 0.67-0.0019 V EF Electric: <=12 KW: 0.97-0.00132 V EF >12kW: 1.73V+155SL Btu/h Where V=storage volume (gal.)
	All Electric Type: 0.904		
Duct Location	Unconditioned, vented attic		
Duct Leakage (%)	10.0% (supply) and 10.0% (return)	5.6% (supply) and 5.6% (return)	14.5 (2003 IECC) and 8.0 (2009 IECC) CFM/100 ft^2 of CFA to outdoors
Duct Insulation (hr-sq.ft.-°F/Btu)	R-8 (supply) and R-4 (return)	R-8 (supply) and R-6 (return)	
HVAC Duct Static Pressure	1		
Supply Air Flow (CFM/ton)	360		
Infiltration Rate (SG)	SLA= 0.00057	SLA= 0.00036	

Methodology

- 17 EEMs for Envelope and Fenestration, HVAC System, domestic hot water (DHW) system, lighting and renewable measures

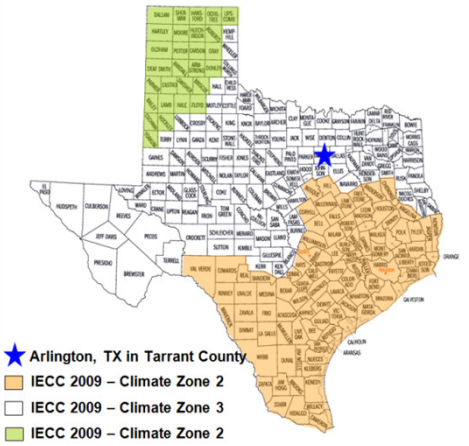
	EEM No.	Electric/Gas House	All-Electric House
Envelope and Fenestration Measures	1	Radiant Barrier in Attics (with Ducts in Attics)	
	2	Sealed (Unvented) Attic	
	3	Window Shading (None to 2 ft. Eaves on All Sides)	
	4	Window Shading and Redistribution (2003 IECC: 27% Equal Windows w/o Shading to S=49%, N=27%, E/W = 16% with 2ft. Eaves on All Sides; 2009 IECC: 23% Equal Windows w/o Shading to S=41%, N=23%, E/W = 14% with 2ft. Eaves on All Sides)	
	5	Decreased Window SHGC (2003 IECC: from .4 to .2; 2009 IECC: from .3 to .2)	
	6	Decreased Window U Value (2003 IECC: from .47 to .3; 2009 IECC: from .5 to .3)	
	7	Decreased Window SHGC & U Value (2003 IECC: from .4 to .2 SHGC & from .47 to .3 U-Value; 2009 IECC: from .3 to .2 SHGC & from .5 to .3 U-Value)	
HVAC System Measures	8	Relocate Mechanical Systems within Conditioned Space	
	9	Improved Air Conditioner SEER (from 13 to 15 SEER)	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)
	10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	-
Domestic Hot Water Measures	11	Tankless Gas Water Heater (without a Standing Pilot Light)	-
	12	Removal of Pilot Light from Domestic Hot Water System	-
	13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	
	14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	
Lighting Measures	15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	
	16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	
Renewable Power Measures	17	4 kW Photovoltaic Array	

Proposed Energy Efficiency Measures (EEMs)

2003 IECC Code-Compliant House with Natural Gas Heating

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	**1.8%**	2.1%	$44		$300 - $880	6.7 - 19.8
2	Sealed (Unvented) Attic	**9.4%**	7.6%	$141	$2,000 - $3,500		14.2 - 24.8
3	Window Shading (None to 2 ft. Eaves on All Sides)	**1.3%**	3.1%	$75		$800 - $1,000	10.7 - 13.4
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)	**3.7%**	4.9%	$107		$800 - $1,000	7.5 - 9.3
5	Decreased Window SHGC (from .4 to .2)	**-1.0%**	3.8%	$111	$200 - $400		1.8 - 3.6
6	Decreased Window U Value (from .47 to .3)	**3.4%**	4.0%	$84	$600 - $900		7.1 - 10.7
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)	**1.6%**	7.1%	$183	$900 - $1,100		4.9 - 6.0
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	**11.1%**	10.4%	$205	$1,000 - $7,000		4.9 - 34.1
9	Improved Air Conditioner SEER (from 13 to 15 SEER)	**4.1%**	5.9%	$133	$900 - $2,500		6.8 - 18.8
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	**3.5%**	1.6%	$20	$800 - $1,300		39.1 - 63.5
C	**Domestic Hot Water Measures**						
11	Tankless Gas Water Heater (without a Standing Pilot Light)	**3.9%**	1.8%	$23	$900 - $1,400		39.1 - 60.8
12	Removal of Pilot Light from Domestic Hot Water System	**1.8%**	0.9%	$11	$100 - $500		9.2 - 46.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	**11.6%**	4.1%	$32		$2,200 - $3,000	67.7 - 92.4
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	**14.6%**	5.6%	$51		$3,200 - $4,000	63.2 - 79.0
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**2.9%**	5.0%	$115	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**5.8%**	10.1%	$234	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	**23.2%**	31.3%	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**9.1%**	16.5%	$378	$50 - $215		3.3 - 5.8	5.4	3.6	2.2
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**12.9%**	16.9%	$362	$50 - $215		4.8 - 11.1	5.2	3.2	2.2
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	**16.8%**	15.9%	$308	$1,000 - $7,000		8.8 - 30.5	4.4	2.3	2.0
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
	Combination 4									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**15.0%**	18.0%	$380	$50 - $215		4.6 - 7.9	5.5	3.3	2.4
6	Decreased Window U Value (from .47 to .3)				$600 - $900					
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)					$800 - $1,000				
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 5									
15	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**17.2%**	19.0%	$389	$50 - $215		6.0 - 12.6	5.6	3.2	2.5
6	Decreased Window U Value (from .47 to .3)				$600 - $900					
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Savings depend on fuel mix used.
   * Energy Cost: Electricity = $0.11/kWh
     Natural gas = $0.64/therm
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

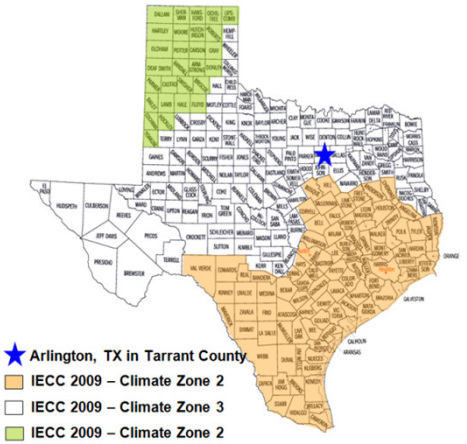
[2003 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 18% (Window-to-wall ratio: 27.1%)
* Lighting: 50% Energy Star permanent CFL or fluorescent lamps
* HVAC system: SEER 13 AC and 0.78 AFUE furnace
* DHW: 0.59 EF NG heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 14.5 cfm/100 sq-ft CFA

Proposed Energy Efficiency Measures (EEMs)

2003 IECC Code-Compliant House with Heat Pump Heating

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	**2.0%**	2.0%	$48		$300 - $880	6.2 - 18.2
2	Sealed (Unvented) Attic	**6.4%**	6.4%	$152	$2,000 - $3,500		13.2 - 23.1
3	Window Shading (None to 2 ft. Eaves on All Sides)	**3.3%**	3.3%	$77		$800 - $1,000	10.3 - 12.9
4	Window Shading and Redistribution (27.1% Equal Windows on All Sides with No Shading to S=48.8%, N=27.1%, E/W = 13.6% with 2ft. Eaves on All Sides)	**4.7%**	4.7%	$113		$800 - $1,000	7.1 - 8.9
5	Decreased Window SHGC (from .4 to .2)	**4.5%**	4.5%	$106	$200 - $400		1.9 - 3.8
6	Decreased Window U Value (from .47 to .3)	**3.7%**	3.7%	$87	$600 - $900		6.9 - 10.3
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)	**7.6%**	7.6%	$181	$900 - $1,100		5.0 - 6.1
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	**8.5%**	8.5%	$203	$1,000 - $7,000		4.9 - 34.5
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)	**6.2%**	6.2%	$148	$1,200 - $2,500		8.1 - 16.9
C	**Domestic Hot Water Measures**						
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	**8.1%**	8.1%	$193		$2,200 - $3,000	11.4 - 15.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	**10.3%**	10.3%	$246		$3,200 - $4,000	13.0 - 16.3
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**5.0%**	5.0%	$119	$25 - $110		0.2 - 0.9
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**9.9%**	9.9%	$235	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	**29.1%**	29.1%	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**16.4%**	16.4%	$384	$50 - $215		3.3 - 5.7	5.5	3.5	2.3
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	**21.5%**	21.5%	$501	$25 - $110		4.2 - 7.4	7.2	4.5	3.0
7	Decreased Window SHGC & U Value (from .4 to .2 SHGC & from .47 to .3 U-Value)				$900 - $1,100					
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)				$1,200 - $2,500					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	**18.7%**	18.7%	$436	$1,000 - $7,000		9.6 - 25.2	6.3	3.9	2.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)					$3,200 - $4,000				

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Energy Cost: Electricity = $0.11/kWh
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

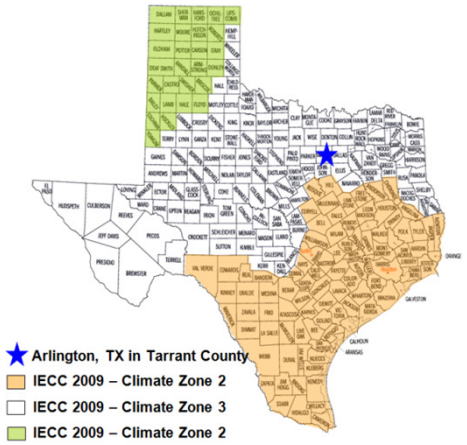
[2003 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 18% (Window-to-wall ratio: 27.1%)
* Lighting: 50% Energy Star permanent CFL or fluorescent lamps
* HVAC system: SEER 13 AC and 7.7 HSPF heat pump
* DHW: 0.90 EF Electric heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 14.5 cfm/100 sq-ft CFA

Proposed Energy Efficiency Measures (EEMs)

2009 IECC Code-Compliant House with Natural Gas Heating

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.8%	**2.0%**	$46		$300 - $880	6.6 - 19.2
2	Sealed (Unvented) Attic	7.6%	**5.7%**	$109	$2,000 - $3,500		18.3 - 32.0
3	Window Shading (None to 2 ft. Eaves on All Sides)	0.6%	**2.0%**	$56		$800 - $1,000	14.2 - 17.8
4	Window Shading and Redistribution (22.6% Equal Windows on All Sides with No Shading to S=40.7%, N=22.6%, E/W = 13.6% with 2ft. Eaves on All Sides)	1.9%	**3.0%**	$73		$800 - $1,000	11.0 - 13.7
5	Decreased Window SHGC (from .3 to .2)	-0.6%	**1.5%**	$50	$200 - $400		4.0 - 8.0
6	Decreased Window U Value (from .5 to .3)	4.2%	**4.2%**	$93	$600 - $900		6.4 - 9.6
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)	3.3%	**5.6%**	$142	$900 - $1,100		6.3 - 7.8
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	9.2%	**8.2%**	$172	$1,000 - $7,000		5.8 - 40.7
9	Improved Air Conditioner SEER (from 13 to 15 SEER)	3.8%	**6.0%**	$150	$900 - $2,500		6.0 - 16.6
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)	4.7%	**2.3%**	$33	$800 - $1,300		24.5 - 39.8
C	**Domestic Hot Water Measures**						
11	Tankless Gas Water Heater (without a Standing Pilot Light)	3.3%	**1.7%**	$23	$900 - $1,400		39.1 - 60.8
12	Removal of Pilot Light from Domestic Hot Water System	1.6%	**0.8%**	$11	$100 - $500		9.2 - 46.0
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	9.9%	**3.7%**	$32		$2,200 - $3,000	67.7 - 92.4
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	12.6%	**5.0%**	$51		$3,200 - $4,000	63.2 - 79.0
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	2.0%	**4.3%**	$112	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	4.2%	**8.7%**	$228	$50 - $215		0.2 - 0.9
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	19.9%	**28.4%**	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Combined Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	8.6%	**15.8%**	$403	$50 - $215		3.1 - 5.4	5.8	3.9	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	13.1%	**17.0%**	$405	$50 - $215		4.3 - 9.9	5.8	3.6	2.5
9	Improved Air Conditioner SEER (from 13 to 15 SEER)				$900 - $2,500					
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	16.0%	**15.0%**	$317	$1,000 - $7,000		8.5 - 29.7	4.6	2.3	2.1
10	Improved Furnace Efficiency (from 0.78 to 0.93 AFUE)				$800 - $1,300					
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Savings depend on fuel mix used.
   * Energy Cost: Electricity = $0.11/kWh
     Natural gas = $0.64/therm
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

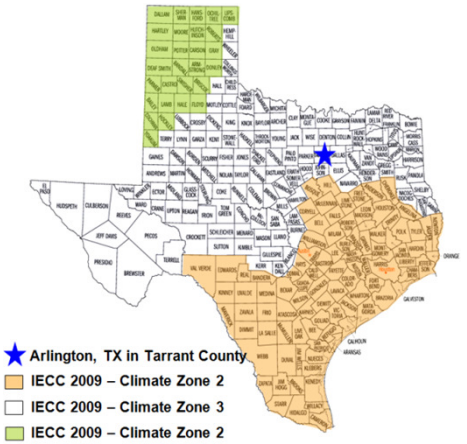
[2009 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 15% (Window-to-wall ratio: 22.6%)
* Lighting: 50% Energy Star permanent CFL or fluorescent lamps
* HVAC system: SEER 13 AC and 0.78 AFUE furnace
* DHW: 0.59 EF NG heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 8 cfm/100 sq-ft CFA

Proposed Energy Efficiency Measures (EEMs)

2009 IECC Code-Compliant House with Heat Pump Heating

Description of Individual Measures

	Individual Measures	Annual Energy Savings (%)[1]		Annual Energy Savings ($/year)[2]	Estimated Cost ($)		Simple Estimated Payback (yrs)
		Site	Source		Marginal Cost[3]	New System Cost[4]	
A	**Envelope and Fenestration Measures**						
1	Radiant Barrier in Attics (with Ducts in Attics)	1.8%	**1.8%**	$45		$300 - $880	6.6 - 19.5
2	Sealed (Unvented) Attic	4.0%	**4.0%**	$103	$2,000 - $3,500		19.4 - 33.9
3	Window Shading (None to 2 ft. Eaves on All Sides)	2.1%	**2.1%**	$55		$800 - $1,000	14.6 - 18.2
4	Window Shading and Redistribution (22.6% Equal Windows on All Sides with No Shading to S=40.7%, N=22.6%, E/W = 13.6% with 2ft. Eaves on All Sides)	2.9%	**2.9%**	$74		$800 - $1,000	10.8 - 13.5
5	Decreased Window SHGC (from .3 to .2)	2.0%	**2.0%**	$52	$200 - $400		3.9 - 7.8
6	Decreased Window U Value (from .5 to .3)	3.8%	**3.8%**	$97	$600 - $900		6.2 - 9.3
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)	5.6%	**5.6%**	$142	$900 - $1,100		6.3 - 7.8
B	**HVAC System Measures**						
8	Relocate Mechanical Systems within Conditioned Space	6.3%	**6.3%**	$161	$1,000 - $7,000		6.2 - 43.4
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)	6.7%	**6.7%**	$171	$1,200 - $2,500		7.0 - 14.6
C	**Domestic Hot Water Measures**						
13	Solar Domestic Hot Water System (32 sq. ft. collector, 65 gal tank)	7.6%	**7.6%**	$193		$2,200 - $3,000	11.4 - 15.6
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)	9.7%	**9.7%**	$246		$3,200 - $4,000	13.0 - 16.3
D	**Lighting Measures**						
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	4.3%	**4.3%**	$110	$25 - $110		0.2 - 1.0
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	8.8%	**8.8%**	$226	$50 - $215		0.2 - 1.0
E	**Renewable Power Measures**						
17	4 kW Photovoltaic Array	27.1%	**27.1%**	$692		$20,000 - $30,000	28.9 - 43.3



Description of Combined Measures

	Combination of Measures[5]	Annual Energy Savings (%)[1]		Combined Energy Savings ($/year)[2]	Combined Estimated Cost ($)		Simple Estimated Payback (yrs)	NOx Emissions Savings	SO_2 Emissions Savings	CO_2 Emissions Savings
		Site	Source		Marginal Cost[3]	New System Cost[4]		Annual (lbs/yr)	Annual (lbs/yr)	Annual (tons[6]/yr)
	Combination 1									
16	100% Energy Star Permanent CFL or Fluorescent Indoor Lamps	15.8%	**15.8%**	$403	$50 - $215		3.1 - 5.4	5.8	3.6	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
1	Radiant Barrier in Attics (with Ducts in Attics)					$300 - $880				
	Combination 2									
15	75% Energy Star Permanent CFL or Fluorescent Indoor Lamps	15.4%	**15.4%**	$393	$25 - $110		5.4 - 9.4	5.7	3.6	2.4
7	Decreased Window SHGC & U Value (from .3 to .2 SHGC & from .5 to .3 U-Value)				$900 - $1,100					
9	Improved Heat Pump Efficiency (from 13 to 15 SEER and from 7.7 to 8.5 HSPF)				$1,200 - $2,500					
	Combination 3									
8	Relocate Mechanical Systems within Conditioned Space	16.0%	**16.0%**	$407	$1,000 - $7,000		10.3 - 27.0	5.9	3.7	2.5
14	Solar Domestic Hot Water System (64 sq. ft. collector, 80 gal tank)					$3,200 - $4,000				

Note:
1. Total energy savings from heating, cooling, lighting, equipment and DHW for emissions reductions determination.
2. Energy Cost: Electricity = $0.11/kWh
3. Marginal cost = new system cost - original system cost
4. New system cost = new system cost only
5. See individual measures above for specific savings
6. Conversion factor: 1 ton = 2,000 lbs

[2009 IECC Code-Compliant House Description]
* Building type: Residential
* Gross area: 2,325 sq-ft
* Building dimension: 48.2ft x 48.2ft x 8ft (WxLxH)
* Number of floors: 1
* Floor-to-floor height: 8ft
* Window-to-floor ratio: 15% (Window-to-wall ratio: 22.6%)
* Lighting: 50% Energy Star permanent CFL or fluorescent lamps
* HVAC system: SEER 13 AC and 7.7 HSPF heat pump
* DHW: 0.90 EF Electric heater
* Duct Location: Unconditioned, vented attic
* Duct Leakage to Outdoor: 8 cfm/100 sq-ft CFA

Questions?